

## SUBSTITUTE SPECIFICATION

### A CLOCK

#### Background of the Invention

The present invention relates to maintaining the accuracy of a clock, and is especially, but not exclusively applicable to clocks within portable radio communication devices, such as radiotelephones.

5 It is well known for a radiotelephone to include time-keeping circuitry which enables it to serve additionally as a clock for the user. Often, the clock is driven from a crystal oscillator the output signal of which is also used as timing base for the other functions which the radiotelephone performs. Sometimes, a dedicated oscillator is provided to drive the clock. 10 In either case, the stability of the output frequency of the oscillator has a great impact on the accuracy of the clock.

Many techniques are known to maintain the stability of the output frequency of the oscillator in the face of influences, 15 such as temperature variation, ageing and the like, which tend to cause the output frequency to drift from its initial value. These known techniques generally increase the cost of the oscillator by, for example, using a more expensive and inherently more robust crystal and/or adding additional circuitry which attempts

5. to compensate for the drift causing influences.

### Summary of the Invention

With this background in mind, according to one aspect,  
the present invention may provide a method for maintaining the  
accuracy of a clock, comprising the steps of: setting the clock  
time on a first occasion; setting the clock time of on a second  
occasion; and adjusting the time-keeping operation of the clock  
on the basis of the time which elapsed between the first and  
second occasions, and the difference in clock time just prior to  
the second occasion and as set on the second occasion.

In this way, the accuracy of the clock can be  
maintained within reasonable bounds in the face of drift-causing  
influences, not by increasing the cost or complexity of the clock  
circuitry itself to arrive at the required accuracy, but by using  
feedback from an external, more accurate source to adjust the  
time-keeping operation of the clock to compensate for the  
drift-causing influences.

Preferably, the clock comprises an oscillator and  
processing means for processing the signal from the oscillator on  
the basis of a timing parameter to produce an indication of clock  
time.

In one embodiment, the time-keeping operation of the  
clock may be adjusted by directly re-tuning the crystal of the

5 oscillator. Alternatively or additionally, the timing parameter  
of the processing means may be adjusted.

The clock time may be set manually by the user.  
Alternatively, where the clock is implemented as part of a radio  
10 communication device, it can be automatically reset from time to  
time from an accurate remote source via the radio interface.

In other embodiments, the clock cannot only passively  
adjust its time-keeping operations to adjust to past conditions,  
but can also based on predictive models of the behaviour of the  
15 oscillator in different environments temperature-wise, the  
behaviour of the oscillator as it ages and the like, the clock  
can also seek to pre-compensate for frequency drift before or as  
it is happening.

According to a further aspect of the invention, the  
20 present invention may provide a clock comprising  
time-setting means to set the clock time; and adjustment means  
for adjusting the time-keeping operation of the clock when the  
clock time is reset.

Preferably, the clock comprises an oscillator and  
25 processing means to process the signal from the oscillator on the  
basis of a timing parameter to produce an indication of clock  
time.

In one embodiment, the adjustment means includes means

5 for re-tuning the oscillator. Alternatively or additionally, the adjustment means is operable to adjust the timing parameter.

According to a further aspect of the invention, the present invention may provide a radio communication device including a clock as previously discussed.

#### Brief Description of the Drawings

Exemplary embodiments of the invention are hereindescribed with reference to the accompanying drawings, in which:

Figures 1 (a) and 1 (b) show schematic hardware layouts for first and second embodiments of the invention, respectively;

Figure 2 is a time line illustrating the present invention; and

Figure 3 is a view of an embodiment of Figure 1 communicating with a base station and the internet.

#### Detailed Description of the Invention

Referring to Figure 1 (a), a cellular radiotelephone 1 in accordance with a first embodiment of the present invention is shown. The radiotelephone comprises a baseband unit 10 for controlling the general operation of the radiotelephone. The baseband unit 10 is also coupled to a display 14, a radio interface 16 by which the telephone can communicate over the air

5 with a base station, a key pad 18. The timing base for the  
baseband unit 10 is provided by a crystal oscillator 30. Also, a  
clock unit 40 also supplies clock time data to the baseband unit  
10 which depending on the mode in which the radiotelephone is  
being used can be displayed on the display 14. The clock unit 40  
10 includes a dedicated crystal oscillator 42 which produces an  
output signal at a nominal frequency  $f$  after it has been tuned  
during manufacture. The clock unit 40 also comprises a  
processing unit 44 which keeps time in clock time format, i.e.,  
date/hours/minutes, and counts the pulses produced by the  
15 oscillator 42 to provide an indication of the passage of time so  
that the clock time be appropriately updated. The processing  
unit 44 also includes semi-permanent memory 45. The clock time  
held by the processing means can be set from the user via the key  
pad 18. The radiotelephone is powered from a removable battery  
20 power supply 35. When the battery power is removed, the  
oscillator clock unit 40 continues to operate normally for a  
short while deriving its power from a large capacitor (not  
shown). Once the capacitor runs down the clock unit 40 stops  
operating.

25 As the radiotelephone leaves the manufacturing process,  
the nominal frequency of the oscillator is accurately known.  
Therefore, the processing unit 44, having a timing parameter  $P$   
set equal to  $f$ , is able to count  $P$  pulses and equate that

5 duration with one second (because  $P=f$ ) and hence accurately  
update its clock time. So when the user initially gets the  
radiotelephone and sets the clock time via the key pad, the  
radiotelephone is able to accurately keep time. When the clock  
time is initially set, this time,  $T_{initial}$ , is stored in the  
10 semi-permanent memory 45. Timing parameter  $P$  is also stored in  
the semi-permanent memory 45. As time goes by, the effects of  
the climate in which the radiotelephone is being used, the ageing  
of the oscillator 42 and the like, causes the actual output of  
the oscillator 42 to drift  $+ \Delta f$ . As a result, when the  
15 processing unit 44 counts  $P=f$  pulses, this no longer equates  
exactly to one second and so the clock time shown by the  
radiotelephone incrementally diverges from the actual time.

When the user resets the time, at time  $T_{end}$ , because he  
has noted that the displayed time is no longer correct, the  
20 processing unit 44 calculates (i)  $t_{period}$ , the time since the clock  
time was last reset,  $T_{end} - T_{initial}$ , and (ii)  $\Delta T$  calculates the  
difference in clock time as the clock is reset,  $T_{reset}$ , and the  
clock time momentarily before the clock time is reset,  $T_{end}$ . By  
calculating  $t_{periods}$ ,  $\Delta T$ , the processing unit 44 can then evaluate  
25 the average error per unit time over the interval  $T_{reset}$  and make a  
correction to the timing parameter  $P$  to reflect this error.

In this way, the processing unit 44 seeks to use the  
knowledge of the time-keeping error made over the interval  $t_{period}$

5 to adjust the time-keeping operation of the clock unit 40 to keep time more accurately in the future.

This corrective process is applied every time the user resets the clock time. From the foregoing, it will be appreciated that  $T_{\text{reset}}$  for one interval becomes  $T_{\text{initial}}$  for the next interval.

10 In Figure 1 (b), in which similar parts have been given the same reference numbers, a radiotelephone 1 in accordance with a second embodiment of the present invention is shown. This embodiment differs from the first embodiment in that the oscillator 30 for driving the baseband unit is dispensed with and, instead, the clock oscillator 42 is used to provide the time base for baseband unit 10 also. In addition, the clock unit 40 includes an oscillator tuning unit 40.

15 20 The operation of this embodiment is the same as the first Figure 1 (a) embodiment except on the basis of the calculated values of  $t_{\text{period}}$  and  $AT$ , the oscillator tuning unit re-tunes the output frequency of the oscillator 44.

25 It will be appreciated that an added advantage of this second embodiment of the invention is that the frequency output of the oscillator 42 is brought back towards its nominal value  $f$  and this is advantageous to the reliability of the operation of the rest of the radiotelephone.

In both embodiments, because the adjust of the

5 time-keeping operation of the clock unit 40 depends on  $T_{\text{initial}}$   
which is stored in the memory 45,  $T_{\text{end}}$  and  $T_{\text{reset}}$ , it is important  
to try and identify situations in which the battery for a  
prolonged has been removed or where the clock time entered by the  
user is erroneous. It will be clear that if these eventualities  
10 are not recognized then it will be possible that the operation of  
the clock unit will be severely distorted and bear little  
resemblance to the passage of actual time. This is particularly  
serious in the case of the second embodiment, where the effect of  
the error will not be localized to the clock unit 40 itself, but  
15 also affect the operation of the other functions of the  
radiotelephone.

Where the battery is removed for a prolonged period,  
only the data in the semi-permanent memory will be retained. On  
powering up the radiotelephone again, the clock time will assume  
a zero default status. As the clock time includes a date field  
as well this condition will be very easy to detect as a zero day  
or month does not exist normally. Where the user enters an  
erroneous clock time, this can be detected by setting a threshold  
for  $\Delta T$  above which it is assumed that there has been a user  
20 error. In both these cases, the time-keeping operation of the  
clock unit 44 is not adjusted.

Another situation in which the time-keeping operation might  
not be adjusted is where  $t_{\text{period}}$  is a very short period.



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In other embodiments of the invention and referring to Figure 3, the radiotelephone 1 automatically requests an accurate version of clock time from a base station 100 of a cellular network, or from the internet 110 which it gains access to via the base station 110. In other embodiments, the base station 100 can regularly update the radiotelephone 1 with the correct clock time which it supplies from its own accurate clock or which it requests from the internet 110.

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In other embodiments, the radio telephone 1 cannot only passively adjust its time-keeping operations to adjust to pas conditions, but can also based on predictive models of the behaviour of the oscillator in different environments temperature-wise, the behaviour of the oscillator as it ages and the like, the clock can seek to pre-compensate for frequency drift before or as it is happening.